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(54) Callus cell induction and the preparation of taxanes

Kallus-Zellen-Induktion und Herstellung von Taxanen

Induction de cellules du callus et préparation de taxanes

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- **IN VITRO PART II vol. 27, no. 3, 1991, US page 109A E.R.M. WICKREMESINHE ET AL. 'Production of Taxol in callus and cell suspension cultures of Taxus media 'Hicksii''**
- **BIOTECHNOLOGY vol. 10, no. 12, December 1992, NEW YORK, US pages 1572 - 1575 A.G. FETT-NETO ET AL. 'Cell culture of Taxus as a source of the antineoplastic drug Taxol and related taxanes'**

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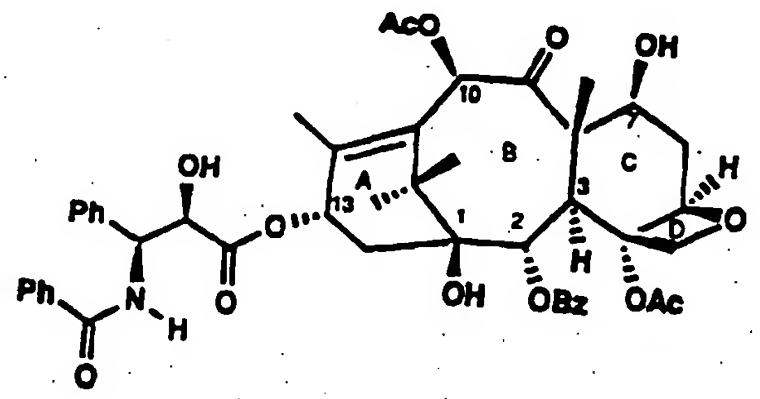
Description

[0001] The present invention relates to a method for the induction of callus cells capable of producing taxanes such as taxol from explant tissues, to the callus cells so produced, and to a method employing these cells in the suspension cell culture preparation of taxanes.

[0002] Taxanes are diterpene compounds which find utility in the pharmaceutical field. For example, taxol, a taxane having the structure:



where Ph is phenyl, Ac is acetyl and Bz is benzoyl has been found to be an effective anticancer agent, particularly useful in the treatment of ovarian cancer.

[0003] Taxanes such as taxol may be found in plant materials, and have been isolated therefrom. Such taxanes may, however, be present in plant materials in relatively small amounts so that, in the case of taxol, for example, large numbers of the slow-growing yew trees forming a source for the compound may be required. The art has thus continued to search for alternate methods for obtaining taxanes such as taxol. Particularly sought are efficient methods for the suspension cell culture preparation of these compounds.

[0004] The present invention provides a method for the induction of callus cells capable of producing at least one taxane from explant tissue, comprising the steps of:

(a) contacting at least part of said explant tissue with a liquid medium without completely submerging said tissue in said medium; and
(b) inducing callus cells to form.

[0005] Induction of callus cells according to the method of the present invention allows direct transfer of the cells so formed to a liquid medium for the suspension cell culture preparation of taxanes, without need of a separate growth or proliferation step, thus shortening the overall development time.

[0006] The present invention also provide callus cells produced by the above method of the present invention, and a method for the use of these cells in the suspension cell culture preparation of taxanes.

[0007] The present invention is described in further detail as follows.

Definitions

[0008] The term "explant tissue", as used herein, denotes tissue from an original plant source, which tissue, for example, has not previously been contacted with an artificial liquid or solid medium for the formation of callus cells.

[0009] The term "induction", as used herein, denotes the initial dedifferentiation from the aforementioned explant tissue to form callus cells.

[0010] The term "callus cell", as used herein, denotes any cell which is dedifferentiated relative to the explant tissue from which it was derived.

[0011] The term "solid medium", as used herein, denotes a medium containing gelling agent(s) in a quantity sufficient for solidification of the medium.

[0012] The term "liquid medium", as used herein, denotes a medium containing gelling agent(s) in a quantity insufficient for solidification of that medium, or which contains no gelling agent(s) at all.

[0013] The term "dispersed cells", as used herein, denotes those callus cells or callus cell clusters which, upon dedifferentiation from explant tissue, do not adhere to the remaining explant tissue and thus become free cells or cell

clusters in the surrounding liquid medium

[0014] The term "membrane raft", as used herein, denotes a sheet-like support structure for the explant tissue, which structure is preferably sufficiently porous to allow transport of nutrients.

[0015] The term "dedifferentiation", as used herein, denotes changes in a differentiated tissue, which changes are of a kind leading to the reversion of cell type to a common cell type.

Explant tissue

[0016] The explant tissue employed in the method of the present invention may be any plant tissue from which callus cells capable of producing a taxane may be induced. Exemplary sources for explant tissue include plants of the family *Taxaceae* such as plants of the genera *Amentotaxus*, *Austrotaxus*, *Pseudotaxus*, *Torreya*, and *Taxus*. Preferred as sources of explant tissue are plants of the genus *Taxus*, particularly the species *T. brevifolia*, *T. baccata*, *T. x media* (*e.g. Taxus media* hicksii), *T. wallichiana*, *T. canadensis*, *T. cuspidata*, *T. floridiana*, *T. celebica* and *T. x hunnewelliana*.

[0017] Any part of the plant from which callus cells may be induced may be employed as the explant source such as the bark, cambium, roots, leaves or needles, stems, branches, twigs, wood, embryos, seeds or seedlings. Preferably, the plant organs comprising the root, stem, leaf or embryo are employed, particularly where the source of root tissue is from the root meristem (growing tip) or root cambrium (root bark), where the stem tissue is from bark, branches or twigs, and where the embryo tissue is from immature embryos or germinated mature embryos from seeds. The age or maturity of the plant employed as the explant source may range from that of immature embryos, embryos, seedlings, up to and including mature trees. Stem tissue is most preferred.

[0018] Preferably, prior to use in the present invention, the explant tissue is sectioned into pieces of a size suitable for use therein, such as sizes ranging from about 1 cm to about 5 cm in length. The surface of the explant tissue is also preferably sterilized before use. Sterilization may be conducted by any appropriate method such as by the use of chlorinated bleach, an alcohol solution such as an ethanol/water (e.g. 70% ethanol) solution, or a mixture thereof. Antimicrobial agents may also be employed to achieve and maintain sterility.

Support

[0019] The explant tissue employed in the present invention is maintained in a position such that at least part of the tissue is in contact with the liquid medium, while complete submersion in the liquid medium, which is undesirable for callus induction, is avoided. Thus, a support may be employed which maintains the explant tissue in a position where a portion of the tissue is in contact with the surrounding atmosphere, most preferably air, while the remaining portion is in contact with the liquid medium.

[0020] Any support so positioning the explant tissue of the present invention may be employed. The explant tissue may, for example, be placed on a membrane raft, which is preferred, or on a sponge. Preferred materials for use as a membrane raft include microporous polypropylene or cellulose acetate. It is preferred that the average diameter of the pores of the raft is smaller than the average diameter of the individual callus cells which are formed. Particularly preferred are those membrane materials which do not allow the transfer of callus cells across the membrane. It is also preferred that the level of the liquid medium be above the level of the membrane raft, such as where the raft is positioned below the level of the liquid medium so that there is liquid both above and below the level of the raft. These embodiments facilitate the formation of dispersed cells, and, especially, clusters of dispersed cells.

Liquid Medium

[0021] Any liquid medium allowing callus induction may be employed. Exemplary liquid media are aqueous media of Gamborg's B5 (Table 1 following), Murashige and Skoog (Table 2 following), Anderson's Rhododendron Basal Salts (Table 3 following), Whites (Table 4 following), as well as variations of these media. Exemplary variations of the aforementioned media include the addition of sugars such as sucrose, glucose or maltose, casamino acids (e.g. 0.2%), enzyme hydrolyzed casein (e.g. 0.02%), and glycine (e.g. 0.002%) and various auxins and cytokinins. The use of aqueous Gamborg's B5 medium is preferred.

Table 1

Composition of Gamborg's B5 Medium	
Basal Salts	
	mg/L
Ammonium sulfate	134.000

Table 1 (continued)

Composition of Gamborg's B5 Medium	
Basal Salts	mg/L
Boric acid	3.000
Calcium chloride anhydrous	113.240
Cobalt chloride hexahydrate	0.025
Cupric sulfate pentahydrate	0.025
Disodium EDTA dihydrate	37.300
Ferrous sulfate heptahydrate	27.800
Magnesium sulfate anhydrous	122.090
Manganese sulfate monohydrate	10.000
Potassium iodide	0.750
Potassium nitrate	2500.000
Sodium molybdate dihydrate	0.250
Sodium phosphate monobasic anhydrous	130.500
Zinc sulfate heptahydrate	2.000
Vitamins	
Myo-inositol	100.0
Thiamine HCl	10.0
Pyridoxine HCl	1.0
Nicotinic acid	1.0
Sugars	
Sucrose	20,000.0
Hormones	
2,4-Dichlorophenoxyacetic acid ("2,4-D")	1.5

Table 2

Composition of Murashige and Skoog Medium	
Basal Salts	mg/L
Boric acid	6.20
Calcium chloride anhydrous	332.20
Cobalt chloride hexahydrate	0.025
Cupric sulfate pentahydrate	0.025
Disodium EDTA dihydrate	37.260
Ferrous sulfate heptahydrate	27.800
Magnesium sulfate anhydrous	180.70
Manganese sulfate monohydrate	16.90
Potassium iodide	0.830
Potassium nitrate	1900.00

Table 2 (continued)

Composition of Murashige and Skoog Medium	
Basal Salts	mg/L
Sodium molybdate dihydrate	0.250
Potassium phosphate monobasic anhydrous	170.00
Zinc sulfate heptahydrate	8.60
Ammonium Nitrate	1650.00
Vitamins	
Myo-inositol	100.0
Thiamine HCl	10.0
Pyridoxine HCl	1.0
Nicotinic acid	1.0
Sugars	
Sucrose	20,000.0
Hormones	
2,4-Dichlorophenoxyacetic acid	1.5

Table 3

Composition of Anderson's Rhododendron Basal Salts Medium	
Basal Salts	mg/L
Ammonium nitrate	400.00
Boric acid	6.200
Calcium chloride anhydrous	332.20
Cobalt chloride hexahydrate	0.025
Cupric sulfate pentahydrate	0.025
Disodium EDTA dihydrate	74.500
Ferrous sulfate heptahydrate	55.70
Magnesium sulfate anhydrous	180.70
Manganese sulfate monohydrate	16.90
Potassium iodide	0.300
Potassium nitrate	480.00
Sodium molybdate dihydrate	0.250
Sodium phosphate monobasic anhydrous	330.60
Zinc sulfate heptahydrate	8.60
Vitamins	
Myo-inositol	100.0

Table 3 (continued)

Composition of Anderson's Rhododendron Basal Salts Medium	
Vitamins	
Thiamine HCl	10.0
Pyridoxine HCl	1.0
Nicotinic acid	1.0
Sugars	
Sucrose	20,000.0
Hormones	
2,4-Dichlorophenoxyacetic acid	1.5

Table 4

Composition of Whites Medium	
Basal Salts	
	mg/L
Boric acid	1.50
Calcium nitrate tetrahydrate	208.40
Cupric sulfate pentahydrate	0.010
Ferric sulfate	2.50
Magnesium sulfate anhydrous	366.20
Manganese sulfate monohydrate	3.788
Potassium iodide	0.750
Potassium nitrate	80.00
Sodium sulfate	200.00
Sodium phosphate monobasic anhydrous	16.50
Zinc sulfate heptahydrate	3.00
Potassium chloride	65.00
Vitamins	
Myo-inositol	100.0
Thiamine HCl	10.0
Pyridoxine HCl	1.0
Nicotinic acid	1.0
Sugars	
Sucrose	20,000.0
Hormones	
2,4-Dichlorophenoxyacetic acid	1.5

Callus Induction

[0022] Callus cells may be induced by holding the explant tissue/liquid medium system at suitable conditions therefor.

[0023] The temperature employed during induction is preferably between about 20°C and about 30°C, most preferably about 22°C. The portion of the explant tissue not in contact with the liquid medium is preferably in contact with air in which the relative humidity is controlled, for example, by tightly sealing the system. The relative humidity may, for example, be near saturation such as between about 80% and about 100%. Diffuse, that is, ordinary room lighting, is preferred.

[0024] The portion of the explant tissue which is in contact with the liquid medium is preferably from about 10% to about 25% of the total volume of the tissue section. Induction is preferably conducted over a period between about 10 days to about 30 days. Gentle agitation of the liquid medium in contact with the explant tissue during induction may be employed, although quiescent conditions are preferred.

[0025] Callus cells may form which remain adhered to the remaining explant tissue and/or which slough off the remaining explant tissue to form free callus cells or cell clusters dispersed in the surrounding liquid medium ("dispersed cells"). Some initial proliferation of the callus cells formed may occur during the present induction method.

[0026] Use of a liquid, rather than solid, medium in the induction of callus cells according to the method of the present invention provides significant advantages. Specifically, use of a solid medium induces callus formation in a relatively dry environment in which the callus cells formed remain adhered to the explant tissue. Callus cells formed in such an environment, in order to ultimately grow and produce taxanes efficiently in liquid suspension cell culture, must be acclimated to a liquid environment. Due to the change in oxygen availability, osmotic differences and the like, callus cells induced on a solid medium, during acclimation to a liquid environment, undergo a decrease in growth rate and taxane production, and may exhibit an increase in cell-type abnormalities and lysis. Moreover, acclimation, particularly when achieved during a separate, subsequent growth or proliferation step, lengthens the overall development time from explant tissue to liquid suspension cell culture.

[0027] The method of the present invention obviates the above difficulties. Callus cells induced in contact with a liquid medium, particularly dispersed callus cells so induced as described above, are more readily acclimated to liquid suspension cell culture conditions. Callus cells induced by the method of the present invention may be transferred directly to a liquid suspension cell culture medium without employing a separate growth or proliferation step. Thus, the induction method of the present invention is efficient in reducing the overall development time from explant tissue to suspension cell culture, improving productivity.

[0028] Other advantages may also be obtained by the method of the present invention. For example, callus induction may be achieved for a longer time period on a liquid, rather than solid, medium so that a greater number of callus cells may be obtained. Undesirable compounds, such as phenolics, produced during callus induction are more readily diffused into the medium and away from the callus induction site when employing a liquid medium. Further, the callus formed by the method of the present invention has a healthy, green appearance and contains fewer brown callus cell areas than callus induced on a solid medium.

[0029] The preferred embodiments of the present invention provide additional advantages. For example, the formation of dispersed cells and dispersed cell clusters is desirable as such cells are most readily acclimated to liquid suspension cell culture conditions. Thus, use of a liquid medium in contact with a sufficient portion of the explant tissue so as to allow and promote the formation of dispersed cells and cell clusters, such as where the level of the liquid medium is above that of the explant tissue supporting structure (e.g. membrane raft), is advantageous.

[0030] Most advantageous is the formation of clusters of dispersed cells. Clusters of dispersed cells, when transferred to a liquid suspension cell culture system, most rapidly achieve the critical mass of cells required for maximum cell growth and taxane output. Thus, use of an explant tissue supporting structure which does not allow the transfer of dispersed cell clusters across the structure is preferred. For example, use of a membrane raft which has pores the average diameter of which is smaller than the average diameter of individual dispersed cells, retains cell clusters above the level of the raft and inhibits the transfer of cells across the membrane during which cell clusters may be broken up into individual cells.

Taxane Production

[0031] The present invention also provides a method for the production of at least one taxane, comprising the steps of:

(A) inducing callus cells capable of producing at least one taxane according the above-described method of the present invention for callus cell induction; and
(B) culturing said cells in a liquid suspension cell culture system to produce said taxane(s).

[0032] It is preferred to proceed from step (A) to step (B) without use of an intermediate, separate growth or prolif-

eration step. By "separate growth or proliferation step", as used herein, is meant transferring the cells to a site physically distinct from that where steps (A) and (B) are conducted, and growing or proliferating callus cells.

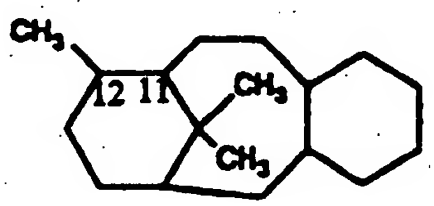
[0033] The suspension cell culture of any taxane capable of being produced by such a method is contemplated within the scope of the present invention. It is understood herein that a single, or two or more taxanes, may be produced during practice of the method of the present invention.

[0034] The culturing step (B) of the above method of the present invention may be carried out according to suspension cell culture methods such as those known to the skilled artisan. See U.S. Patent No. 5,019,504, incorporated by reference. Exemplary media which may be employed include those discussed above with respect to induction media. Agar (e.g. 0.1%) or phytagel (e.g. 0.025%) may optionally further be added to such media. The temperature employed during suspension cell culture is preferably between about 22 and 25°C; the relative humidity employed is preferably between about 40 and about 60%; and the degree of agitation is preferably from about 30 to about 200 revolutions per minute (RPM). Inducers such as fungal elicitors, vanadyl sulfate, 3,4-dichlorophenoxy triethyl(amine), etc. may be added. Taxane production may also be conducted by employing cells which are encapsulated in calcium alginate beads, as well as when in a slurry, e.g. made by incorporation of 0.1% agar into the media.

[0035] Recovery of the taxanes produced during culturing may be accomplished by methods known to the skilled artisan. For example, adsorbent beads may be employed to expedite recovery of taxanes such as taxol. Beads remaining in the culture during the production of taxanes such as taxol may also allow greater production by binding the taxane product(s). Additionally, extraction of the taxane product(s) from the cell supernatant or beads is readily accomplished with solvents such as ether or methylene chloride.

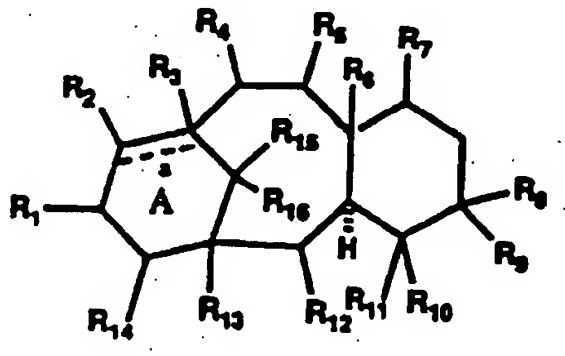
Taxane Compounds

[0036] Taxanes are diterpene compounds containing the taxane carbon skeleton:



which skeleton may contain ethylenic unsaturation in the ring system thereof (e.g., where the 11,12-positions are bonded through an ethylenic linkage). The preparation of all taxanes, whether pharmacologically active or inactive, is contemplated within the scope of the present invention. Taxanes may be produced by the callus cells of the present invention which are (i.e. are naturally occuring), or are not, found in the original explant tissue.

[0037] Exemplary taxanes which may be produced by the cell culture method of the present invention include those of the following formula I:



(I)

where R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}, R_{16} and "a" are as defined in the following Table 5.

Table 5

Compound[4/]	R_1 [1/]	R_2	R_3	R_4	R_5	R_6	R_7 [2/]	R^8
1) taxol	tax	CH_3	H	β-acetyloxy	=O	β-CH_3	β-OH	H
2) 10-desacetyl-cephalomannine	ceph	CH_3	H	β-OH	=O	β-CH_3	β-OH	H
3) 7-epitaxol	tax	CH_3	H	β-acetyloxy	=O	β-CH_3	α-OH	H
4) 10-desacetyl-7-epitaxol	tax	CH_3	H	β-OH	=O	β-CH_3	α-OH	H
5) 7-epicephalomannine	ceph	CH_3	H	β-acetyloxy	=O	β-CH_3	α-OH	H
6) baccatin III	α-OH	CH_3	H	β-acetyloxy	=O	β-CH_3	β-OH	H
7) 10-desacetyl-baccatin III	α-OH	CH_3	H	β-OH	=O	β-CH_3	β-OH	H
8) cephalomannine	ceph	CH_3	H	β-acetyloxy	=O	β-CH_3	β-OH	H
9) 10-desacetyl-taxol	tax	CH_3	H	β-OH	=O	β-CH_3	β-OH	H
10) xylosyl taxol	tax	CH_3	H	β-acetyloxy	=O	β-CH_3	β-xylosyl	H
11) xylosyl cephalomannine	ceph	CH_3	H	β-acetyloxy	=O	β-CH_3	β-xylosyl	H
12) taxagifine	=O	α-CH_3	β-OH	β-acetyloxy	α-acetyloxy	β-CH_3	β-acetyloxy	H
13) 8-benzoyloxy taxagifine	=O	α-CH_3	β-OH	β-acetyloxy	α-acetyloxy	β-benzoyl-oxymethyl	β-acetyloxy	H
14) 9-acetyloxy-taxusin	α-acetyloxy	CH_3	H	β-acetyloxy	α-acetyloxy	β-CH_3	H	H
15) 9-hydroxytaxusin	α-acetyloxy	CH_3	H	β-acetyloxy	α-OH	β-CH_3	H	H
16) taiwanxan	H	CH_3	H	β-acetyloxy	α-acetyloxy	β-CH_3	H	H
17) taxane Ia	tax	CH_3	H	=O	=O	β-CH_3	α-OH	H
18) taxane Ib	taxsub	CH_3	H	=O	=O	β-CH_3	α-OH	H
19) taxane Ic	taxsub	CH_3	H	=O	=O	β-CH_3	α-acetyloxy	H
20) taxane Id	α-acetyloxy	CH_3	H	β-acetyloxy	α-acetyloxy	β-CH_3	β-acetyloxy	H
21) 7-epibaccatin III	α-OH	CH_3	H	β-acetyloxy	=O	β-CH_3	α-OH	H
22) taxotere	taxot	CH_3	H	β-OH	=O	β-CH_3	β-OH	H

Table 5 (Continued)

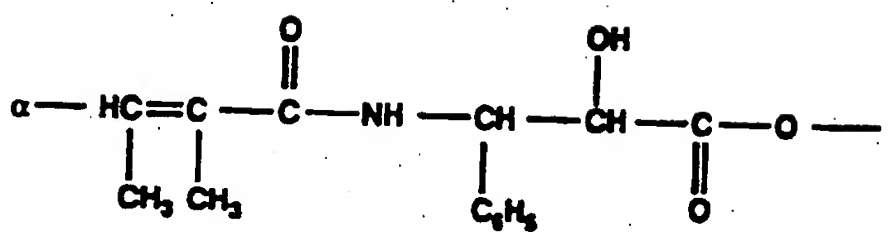
Compound[4/]	R_9 [5/]	R_{10}	R_{11}	R_{12}	R_{13}
1) taxol	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
2) 10-desacetyl-cephalomannine	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
3) 7-epitaxol	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
4) 10-desacetyl-7-epitaxol	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
5) 7-epicephalo-mannine	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
6) baccatin III	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
7) 10-desacetyl-baccatin III	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
8) cephalomannine	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
9) 10-desacetyl-taxol	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
10) xylosyl taxol	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
11) xylosyl cephalomannine	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
12) taxagifine	α-cinnamoyloxy	methylene (=CH_2)		α-acetyloxy	β-H
13) 8-benzoyloxy taxagifine	α-cinnamoyloxy	methylene (=CH_2)		α-acetyloxy	β-H
14) 9-acetyloxy taxusin	α-acetyloxy	methylene (=CH_2)		H	H
15) 9-hydroxy taxusin	α-acetyloxy	methylene (=CH_2)		H	H
16) taiwanxan	α-OH	methylene (=CH_2)		α-acetyloxy	H
17) taxane Ia	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
18) taxane Ib	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
19) taxane Ic	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
20) taxane Id	α-OH	epoxide		α-acetyloxy	β-OH
21) 7-epibaccatin III	oxetane		α-acetyloxy	α-benzoyloxy	β-OH
22) taxotere	oxetane		α-acetyloxy	α-benzoyloxy	β-OH

Table 5 (Cont'd)

Compound[4/]	R_{14}	R_{15}	R_{16}	a [3/]
1) taxol	H	CH_3	CH_3	X
2) 10-desacetyl-cephalomannine	H	CH_3	CH_3	X
3) 7-epitaxol	H	CH_3	CH_3	X
4) 10-desacetyl-7-epitaxol	H	CH_3	CH_3	X
5) 7-epicephalo-mannine	H	CH_3	CH_3	X
6) baccatin III	H	CH_3	CH_3	X
7) 10-desacetyl-baccatin III	H	CH_3	CH_3	X
8) cephalomannine	H	CH_3	CH_3	X
9) 10-desacetyl-taxol	H	CH_3	CH_3	X
10) xylosyl taxol	H	CH_3	CH_3	X
11) xylosylceph-alomannine	H	CH_3	CH_3	X
12) taxagifine	H	cyclo [6/]	α-CH_3	-
13) 8-benzoyloxy taxagifine	H	cyclo	α-CH_3	-
14) 9-acetyloxy taxusin	H	CH_3	CH_3	X
15) 9-hydroxy taxusin	H	CH_3	CH_3	X
16) taiwanxan	2-methylbuta-noyloxy	CH_3	CH_3	X
17) taxane Ia	H	CH_3	CH_3	X
18) taxane Ib	H	CH_3	CH_3	X
19) taxane Ic	H	CH_3	CH_3	X
20) taxane Id	H	CH_3	CH_3	X
21) 7-epibaccatin III	H	CH_3	CH_3	X
22) taxotere	H	CH_3	CH_3	X

Footnotes

1/ "ceph" denotes



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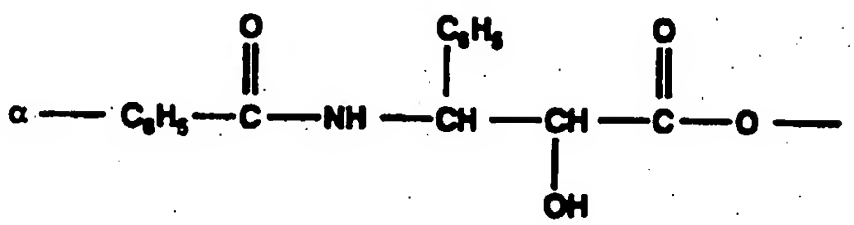
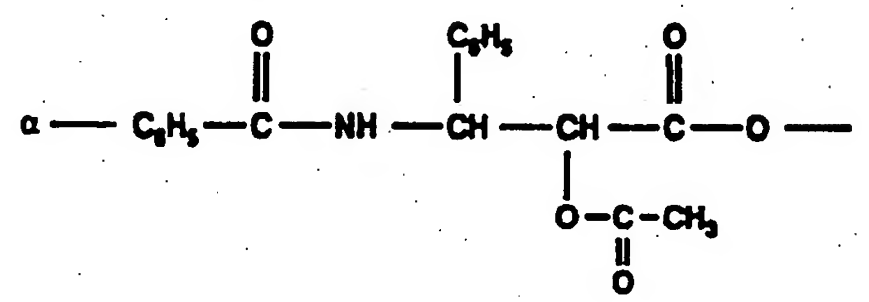
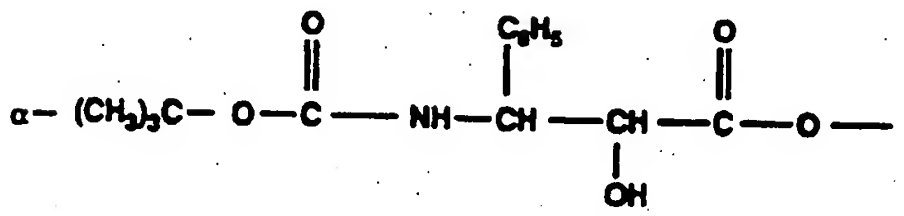


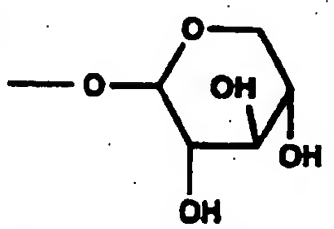
"taxsub" denotes



"taxot" denotes



2/ "xylosyl" denotes

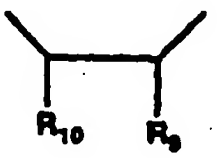


3/ "a" denotes a double bond present between the 11- and 12-positions

4/ "α" denotes the stereoposition of a moiety below the plane of the taxane ring structure shown above

"β" denotes the stereoposition of a moiety above the plane of the taxane ring structure shown above

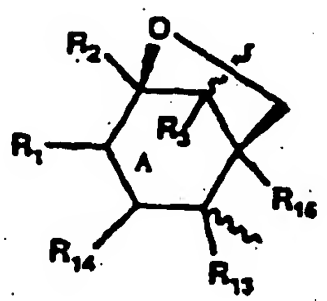
5/ "oxetane" denotes the moiety



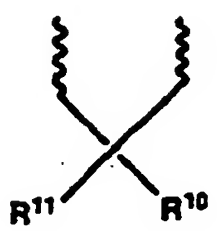
which is

6/ "cyclo" denotes the cyclic group formed by bonding the group "

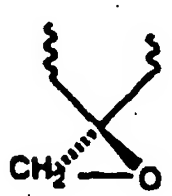
" to the taxane A ring as follows:



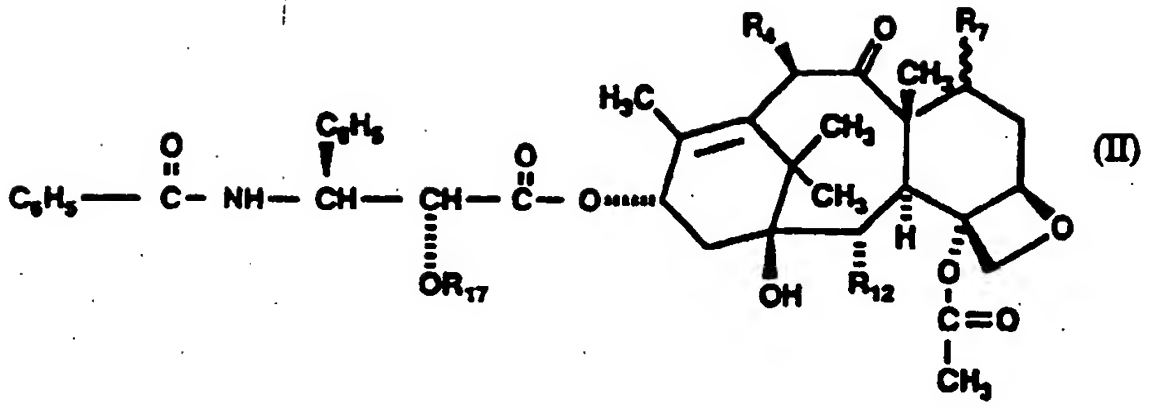
7/ "epoxide" denotes the moiety



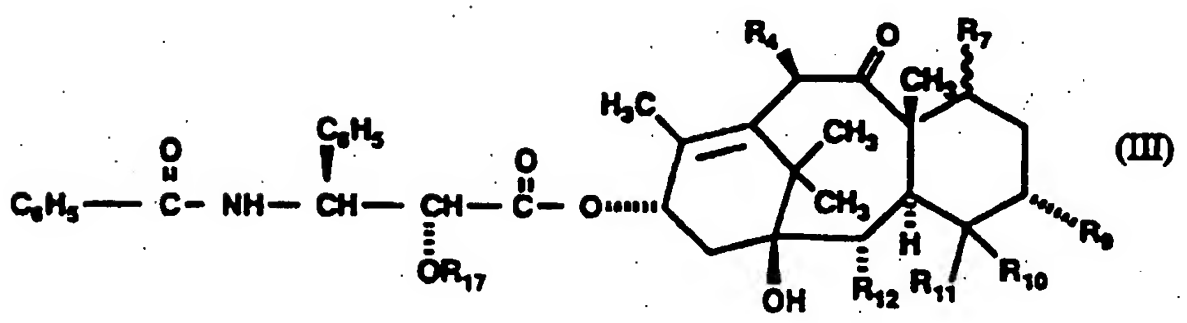
which is



[0038] Taxanes which may be produced by the cell culture method of the present invention may also be represented by the following formulae II or III:



(II)



(III)

where

R_4	is keto (=O) or acetyloxy;
R_7	is hydrogen, α-hydroxy or β-hydroxy;
R_9	is acetyloxy, cinnamoyloxy or hydroxyl;
R_{10} and R_{11}	together form a methylene or epoxide group;
R_{12}	is hydrogen, benzoyloxy or acetyloxy; and
R_{17}	is hydrogen or acetyloxy.

[0039] Preferred taxanes include taxol, baccatin III, 10-desacetylbaccatin III, 10-desacetyl taxol, xylosyl taxol, 7-epi-taxol, 7-epibaccatin III and 10-desacetyl-7-epitaxol. Cell culture production of taxol is a particularly preferred embodiment of the present invention.

[0040] Taxanes are compounds which find utility in the pharmaceutical field, such as in the treatment of cancer. Taxol is exemplary of the pharmacologically active taxanes which also include, for example, cephalomannine, the latter reported as a chemotherapeutic agent for the remission of leukemia in U.S. Patent No. 4,206,221. The present invention contemplates preparation of such pharmacologically active taxanes, as well as preparation of slightly active or inactive taxanes, or those having a less desired activity, which may be used as intermediates to prepare other, pharmacologically active taxanes. The method of the present invention may thus facilitate preparation of pharmacologically active taxanes by providing an efficient means for obtaining the taxane starting material through cell culture.

[0041] The methods of the present invention are further described by the following Examples. These Examples are illustrative only, and are in no way intended to limit the scope of the instant claims.

Example 1

Induction of Callus Cells and Preparation of Taxol

[0042] Explants were cut from *Taxus media hicksii* plant stems after sterilizing in 70% alcohol and 25% bleach. Each explant, approximately 2 - 3 cm in length, was placed on a microporous polypropylene membrane raft which was floating on a medium consisting of Gamborg's B5 Basal salts and vitamins (see previous Table 1), sucrose (2%), 2,4-D (1.5 mg/L) and casamino acids (2 g/L). The medium and raft were contained in a 4 x 4 inch polycarbonate container fitted with a tight polypropylene lid so as to maintain high humidity.

[0043] Prior to placing the explant on the raft, the vessel and medium were autoclaved under standard conditions

for 15 minutes. After placing the explant on the raft, 5 - 10 ml of the above medium were placed on top of the explant. The raft vessel was incubated at 22°C for 3 - 4 weeks until a callus had been generated. After incubation, the explant and callus were removed and the loose cells remaining on the raft were pipetted off and added to 25 ml of the above Gamborg's medium to which had been added 0.1 g/L agar in a 125 ml flask. The loose cells from several rafts may be combined into one flask if cell numbers appear to be low. The inoculated flask was incubated at 22°C on a 50 RPM shaker with 45% humidity and diffuse light.

[0044] After 3 weeks, flasks were harvested and analyzed for taxol. Suspension flasks were found to contain 0.01 to 0.02 mg/L taxol or expressed on a dry cell weight basis: 0.0002 to 0.0004% taxol based on dry cell weight. The presence of other taxanes including cephalomannine and baccatin III was also detected. (Based on two runs as follows:

Run	Taxol Obtained (µg/ml)	Dry Cell weight (mg/ml)
1	0.0207	5.5
2	0.0131	5.7)

Example 2

Variation In Medium

[0045] Explants were cut from *Taxus media hicksii* plant stems after sterilizing in 70% alcohol and 25% bleach. Each explant, approximately 2 - 3 cm in length, was placed on a microporous polypropylene membrane raft which was floating on a medium consisting of Anderson's Rhododendron basal salts (see previous Table 3) and Gamborg's vitamins (see previous Table 1), sucrose (2%), 2,4-D (1.5 mg/L) and casamino acids (2 g/L). The medium and raft were contained in a 4 x 4 inch polycarbonate container fitted with a tight polypropylene lid so as to maintain high humidity.

[0046] Prior to placing the explant on the raft, the vessel and medium were autoclaved under standard conditions for 15 minutes. After placing the explant on the raft, 5 - 10 ml of the above medium were placed on top of the explant. The raft vessel was incubated at 22°C for 5 - 10 weeks until a callus had been generated. After incubation, the explant and callus were removed and the loose cells remaining on the raft were pipetted off and added to 25 ml of the above Anderson's medium to which had been added 0.1 g/L agar in a 125 ml flask. (Loose cells from several rafts may be combined as described above in Example 1.) The inoculated flask was incubated at 22°C on a 50 RPM shaker with 45% humidity and diffuse light.

[0047] After 3 weeks, flasks were harvested and analyzed for taxol. Suspension flasks were found to contain 0.0194 mg/L taxol or expressed on a dry cell weight basis: 0.0062% taxol based on dry cell weight.

Claims

1. A method for the induction of callus cells capable of producing at least one taxane from explant tissue, comprising the steps of:

   (a) contacting at least part of said explant tissue with a liquid medium without completely submerging said tissue in said medium; and
   (b) inducing callus cells to form.

2. The method of claim 1, wherein said explant tissue is obtained from a plant of the family *Taxaceae*.

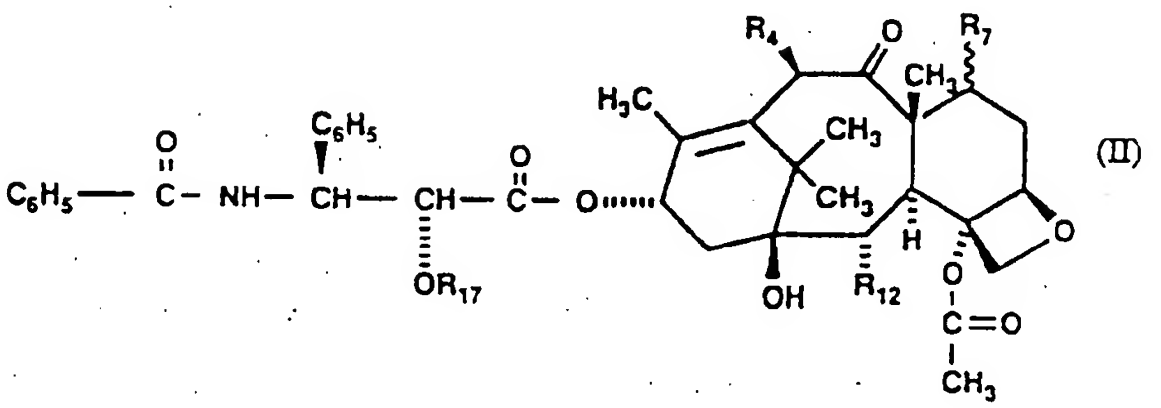
3. The method of claim 2, wherein said plant is selected from the species *T. brevifolia, T. baccata, T. X media, T. wallichiana, T. canadensis, T. cuspidata, T. floridiana, T. celebica* and *T. x hunnewelliana*.

4. The method of any of claims 1 to 3, wherein said at least one taxane is taxol, 10-desacetylcephalomannine, 7-epitaxol, 10-desacetyl-7-epitaxol, 7-epicephalomannine, baccatin III, taxotere, 10-desacetylbaccatin III, cephalomannine, 10-desacetyltaxol, xylosyl taxol, xylosyl cephalomannine, 7-epibaccatin III, taxagifine, 8-benzoyloxy taxagifine, 9-acetyloxy taxusin, 9-hydroxy taxusin, taiwanxam, taxane Ia, taxane Ib, taxane Ic and/or taxane Id.

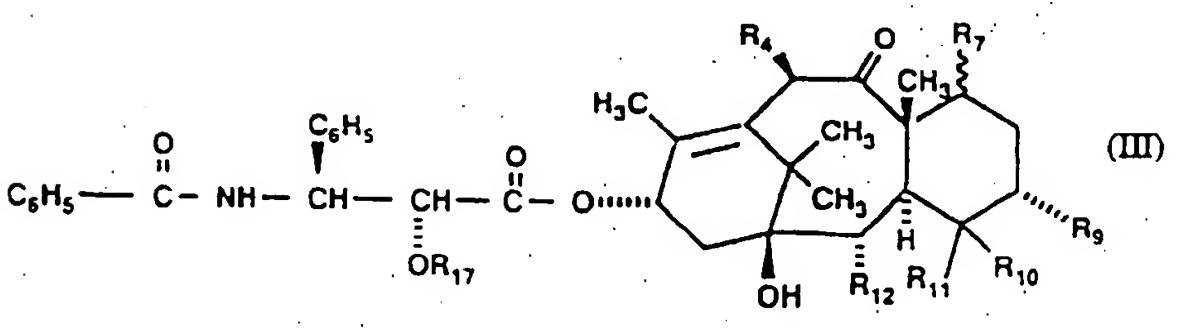
5. The method of claim 4, wherein said at least one taxane is taxol, baccatin III, 10-desacetylbaccatin III, 10-desacetyltaxol, xylosyl taxol, 7-epibaccatin III, 7-epitaxol and/or 10-desacetyl-7-epitaxol.

6. The method of claim 5, wherein said taxane is taxol.

7. The method of any of claims 1 to 3, wherein said at least one taxane is a taxane of the formula II and/or III:



(II)



(III)

where

R_4	is keto (=O) or acetyloxy;
R_7	is hydrogen, α-hydroxy or β-hydroxy;
R_9	is acetyloxy, cinnamoyloxy or hydroxyl;
R_{10} and R_{11}	together form a methylene or epoxide group;
R_{12}	is hydrogen, benzoyloxy or acetyloxy; and
R_{17}	is hydrogen or acetyloxy.

8. The method of any of claims 1 to 7, wherein said explant tissue is supported on a membrane raft or sponge.

9. The method of claim 8, wherein said explant tissue is supported on a membrane raft.

10. The method of claim 9, wherein said membrane raft is microporous polypropylene or cellulose acetate.

11. The method of claim 9 or 10, wherein the level of said liquid medium is above the level of said raft.

12. The method of claim 11, wherein dispersed callus cells or dispersed cell clusters are formed and, further, wherein at least some of said dispersed cells or cell clusters remain above the level of said raft.

13. The method of any of claims 9 to 12, wherein said raft is a porous structure in which the average diameter of the pores is smaller than the average diameter of the individual dispersed cells.

14. The method of any of claims 1 to 13, wherein said liquid medium is aqueous Gamborg's B5 medium, Murashige and Skoog medium, Anderson's Rhododendron Basal Salts medium or Whites medium.

15. The method of claim 14, wherein said liquid medium is aqueous Gamborg's B5 medium.

16. The method of any of claims 1 to 15, wherein the part of said explant tissue which is in contact with said liquid medium is from about 10% to about 25% of the total volume of said tissue.

17. A method for the production of at least one taxane, comprising the steps of:

(A) inducing callus cells capable of producing at least one taxane according to the method of any of claims 1 to 16; and
(B) culturing said cells in a liquid suspension cell culture system to produce said taxane(s).

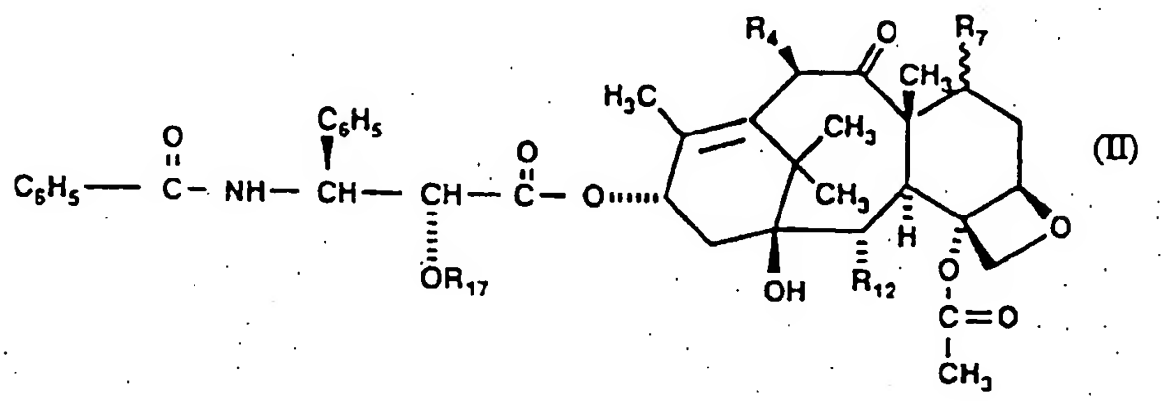
18. The method of claim 17, wherein no separate growth or proliferation step is employed subsequent to step (A) and before step (B).

19. The method of claim 17 or 18, wherein said at least one taxane is taxol, 10-desacetylcephalomannine, 7-epitaxol, 10-desacetyl-7-epitaxol, 7-epicephalomannine, baccatin III, taxotere, 10-desacetylbaccatin III, cephalomannine, 10-desacetyltaxol, xylosyl taxol, xylosyl cephalomannine, 7-epibaccatin III, taxagifine, 8-benzoyloxy taxagifine, 9-acetyloxy taxusin, 9-hydroxy taxusin, taiwanxam, taxane Ia, taxane Ib, taxane Ic and/or taxane Id.

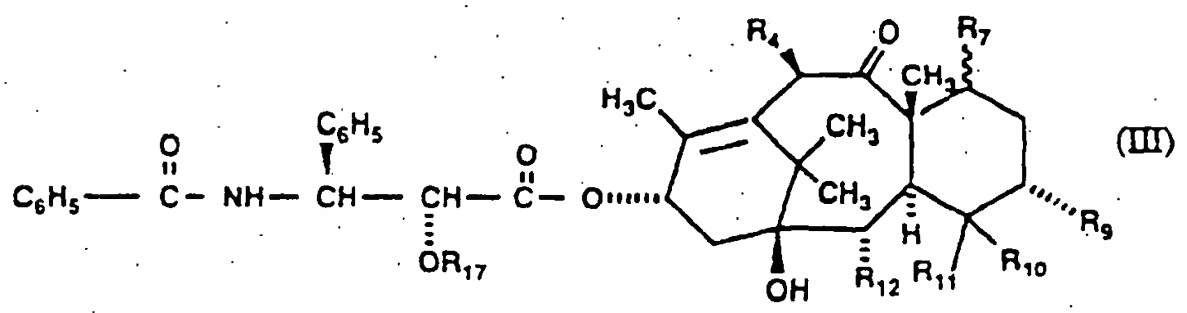
20. The method of claim 19, wherein taxol, baccatin III, 10-desacetylbaccatin III, 10-desacetyltaxol, xylosyl taxol, 7-epibaccatin III, 7-epitaxol, and/or 10-desacetyl-7-epitaxol is produced.

21. The method of claim 20, wherein taxol is produced.

22. The method of claim 17, wherein a taxane of the following formula II and/or III is produced:



(II)



(III)

where

R_4	is keto (=O) or acetyloxy;
R_7	is hydrogen, α-hydroxy or β-hydroxy;
R_9	is acetyloxy, cinnamoyloxy or hydroxyl;
R_{10} and R_{11}	together form a methylene or epoxide group;
R_{12}	is hydrogen, benzoyloxy or acetyloxy; and
R_{17}	is hydrogen or acetyloxy.

23. The method of any of claims 1 to 16, wherein said explant tissue has not previously been contacted with an artificial liquid or solid medium for the formation of callus cells.

24. The method of any of claims 17 to 22, wherein said explant tissue has not previously been contacted with an artificial liquid or solid medium for the formation of callus cells.

Patentansprüche

1. Verfahren zur Induktion von Callus-Zellen, die mindestens ein Taxan aus Explantatgewebe erzeugen können, umfassend die Schritte:

   (a) Inkontaktbringen mindestens eines Teils des Explantatgewebes mit einem flüssigen Medium ohne vollständiges Eintauchen des Gewebes in das Medium; und
   (b) Induzieren der Erzeugung von Callus-Zellen.

2. Verfahren nach Anspruch 1, wobei das Explantatgewebe aus einer Pflanze der Familie Taxaceae erhalten wird.

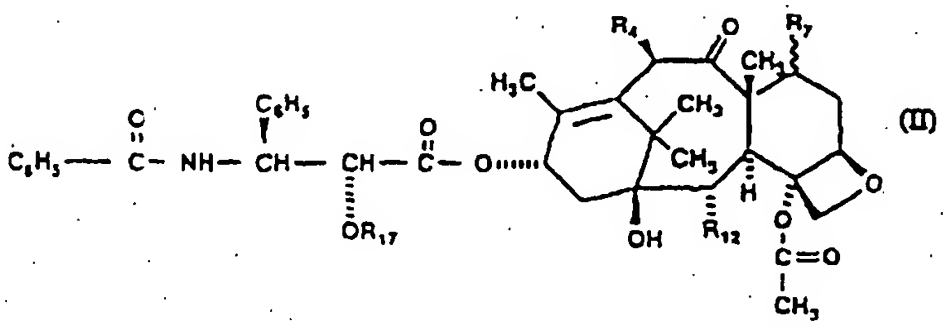
3. Verfahren nach Anspruch 2, wobei die Pflanze ausgewählt ist aus den Arten T. brevifolia, T. baccata, T. x media, T. wallichiana, T. canadensis, T. cuspidata, T. floridiana, T. celebica und T. x hunnewelliana.

4. Verfahren nach einem der Ansprüche 1 bis 3, wobei das mindestens eine Taxan Taxol, 10-Desacetylcephalomannin, 7-Epitaxol, 10-Desacetyl-7-epitaxol, 7-Epicephalomannin, Baccatin III, Taxoter, 10-Desacetylbaccatin III, Cephalomannin, 10-Desacetyltaxol, Xylosyltaxol, Xylosylcephalomannin, 7-Epibaccatin III, Taxagifin, 8-Benzoyloxytaxagifin, 9-Acetyloxytaxusin, 9-Hydroxytaxusin, Taiwanxam, Taxan Ia, Taxan Ib, Taxan Ic und/oder Taxan Id ist.

5. Verfahren nach Anspruch 4, wobei das mindestens eine Taxan Taxol, Baccatin III, 10-Desacetylbaccatin III, 10-Desacetyltaxol, Xylosyltaxol, 7-Epibaccatin III, 7-Epitaxol und/oder 10-Desacetyl-7-epitaxol ist.

6. Verfahren nach Anspruch 5, wobei das Taxan Taxol ist.

7. Verfahren nach einem der Ansprüche 1 bis 3, wobei das mindestens eine Taxan ein Taxan der Formel II und/oder III ist:



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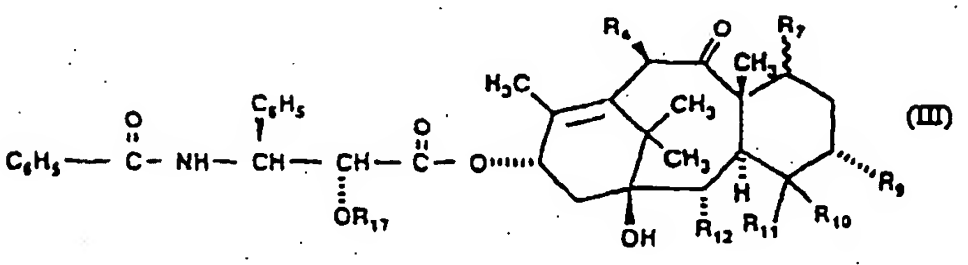


(III)

in denen

R_4 eine Ketogruppe (=O) oder eine Acetyloxygruppe bedeutet;
R_7 ein Wasserstoffatom, eine α-Hydroxy- oder β-Hydroxygruppe bedeutet;
R_9 eine Acetyloxy-, Cinnamoyloxy- oder Hydroxylgruppe bedeutet;
R_{10} und R_{11} zusammen eine Methylen- oder Epoxidgruppe darstellen;
R_{12} ein Wasserstoffatom, eine Benzyloxy- oder Acetyloxygruppe bedeutet; und

R_{17} ein Wasserstoffatom oder eine Acetyloxygruppe bedeutet.

8. Verfahren nach einem der Ansprüche 1 bis 7, wobei das Explantatgewebe sich auf einem Membranfloß oder Schwamm als Träger befindet.

9. Verfahren nach Anspruch 8, wobei das Explantatgewebe sich auf einem Membranfloß als Träger befindet.

10. Verfahren nach Anspruch 9, wobei das Membranfloß mikroporöses Polypropylen oder Celluloseacetat ist.

11. Verfahren nach Anspruch 9 oder 10, wobei das Niveau des flüssigen Mediums oberhalb des Niveaus des Floßes liegt.

12. Verfahren nach Anspruch 11, wobei dispergierte Callus-Zellen oder dispergierte Zellcluster erzeugt werden und wobei außerdem mindestens einige der dispergierten Zellen oder Zellcluster oberhalb des Niveaus des Floßes verbleiben.

13. Verfahren nach einem der Ansprüche 9 bis 12, wobei das Floß eine poröse Struktur aufweist, in der der mittlere Durchmesser der Poren geringer ist als der mittlere Durchmesser der einzelnen dispergierten Zellen.

14. Verfahren nach einem der Ansprüche 1 bis 13, wobei das flüssige Medium wässeriges Gamborg B5-Medium, Murashige- und Skoog-Medium, Anderson-Rhododendron-Basal-Salts-Medium oder Whites-Medium ist.

15. Verfahren nach Anspruch 14, wobei das flüssige Medium wässeriges Gamborg B5-Medium ist.

16. Verfahren nach einem der Ansprüche 1 bis 15, wobei der Teil des Explantatgewebes, der mit dem flüssigen Medium in Kontakt ist, von etwa 10 bis etwa 25 % des Gesamtvolumens des Gewebes beträgt.

17. Verfahren zur Erzeugung mindestens eines Taxans, umfassend die Schritte:

(A) Induzieren von Callus-Zellen, die mindestens ein Taxan erzeugen können, gemäß dem Verfahren nach einem der Ansprüche 1 bis 16; und
(B) Züchten der Zellen in flüssiger Suspension in einem Zellkultursystem zur Herstellung des/der Taxans/e.

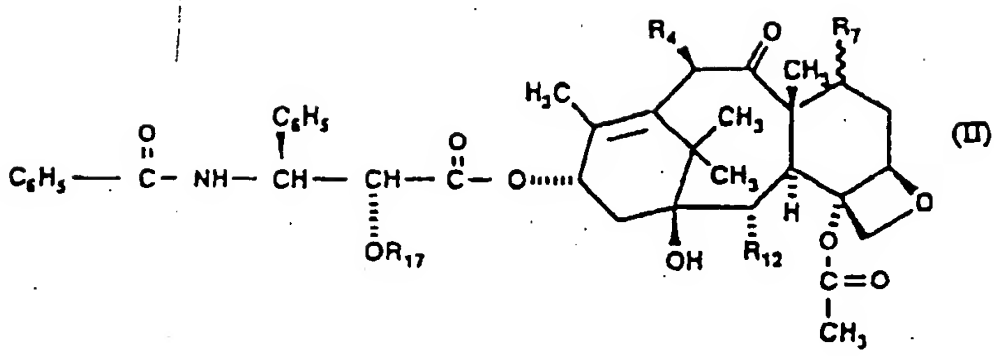
18. Verfahren nach Anspruch 17, wobei kein gesonderter Wachstums- oder Vermehrungsschritt nach dem Schritt (A) und vor dem Schritt (B) verwendet wird.

19. Verfahren nach Anspruch 17 oder 18, wobei das mindestens eine Taxan Taxol, 10-Desacetylcephalomannin, 7-Epitaxol, 10-Desacetyl-7-epitaxol, 7-Epicephalomannin, Baccatin III, Taxoter, 10-Desacetylbaccatin III, Cephalomannin, 10-Desacetyltaxol, Xylosyltaxol, Xylosylcephalomannin, 7-Epibaccatin III, Taxagifin, 8-Benzoyloxytaxagifin, 9-Acetyloxytaxusin, 9-Hydroxytaxusin, Taiwanxam, Taxan Ia, Taxan Ib, Taxan Ic und/oder Taxan Id ist.

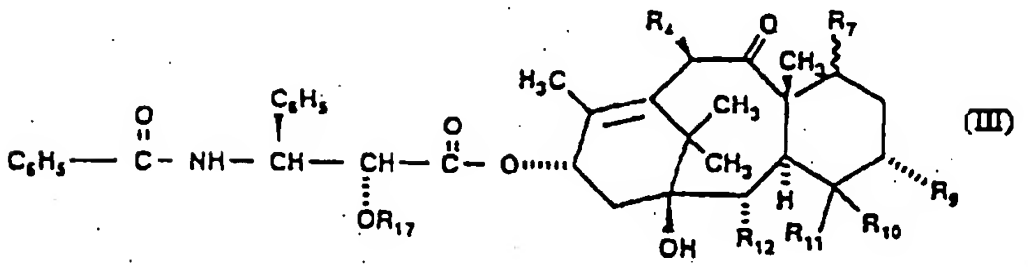
20. Verfahren nach Anspruch 19, wobei Taxol, Baccatin III, 10-Desacetylbaccatin III, 10-Desacetyltaxol, Xylosyltaxol, 7-Epibaccatin III, 7-Epitaxol und/oder 10-Desacetyl-7-epitaxol erzeugt wird.

21. Verfahren nach Anspruch 20, wobei Taxol erzeugt wird.

22. Verfahren nach Anspruch 17, wobei ein Taxan der nachstehenden Formel II und/oder III erzeugt wird:



(II)



(III)

in denen

R_4 eine Ketogruppe (=O) oder eine Acetyloxygruppe bedeutet;
R_7 ein Wasserstoffatom, eine α-Hydroxy- oder β-Hydroxygruppe bedeutet;
R_9 eine Acetyloxy-, Cinnamoyloxy- oder Hydroxylgruppe bedeutet;
R_{10} und R_{11} zusammen eine Methylen- oder Epoxidgruppe darstellen;
R_{12} ein Wasserstoffatom, eine Benzyloxy- oder Acetyloxygruppe bedeutet; und
R_{17} ein Wasserstoffatom oder eine Acetyloxygruppe bedeutet.

23. Verfahren nach einem der Ansprüche 1 bis 16, wobei das Explantatgewebe vorher nicht mit einer künstlichen Flüssigkeit oder einem festen Medium zur Erzeugung von Callus-Zellen in Kontakt gebracht wurde.

24. Verfahren nach einem der Ansprüche 17 bis 22, wobei das Explantatgewebe vorher nicht mit einer künstlichen Flüssigkeit oder einem festen Medium zur Erzeugung von Callus-Zellen in Kontakt gebracht wurde.

Revendications

1. Méthode pour l'induction de cellules de cal capables de produire au moins un taxane à partir d'un tissu d'explant comprenant les étapes de :

   (a) mettre au moins une partie dudit tissu d'explant en contact avec un milieu liquide sans submerger complètement ledit tissu dans ledit milieu ; et
   (b) induire les cellules de cal à se former.

2. Méthode de la revendication 1 où ledit tissu d'explant est obtenu d'une plante de la famille *Taxaceae*.

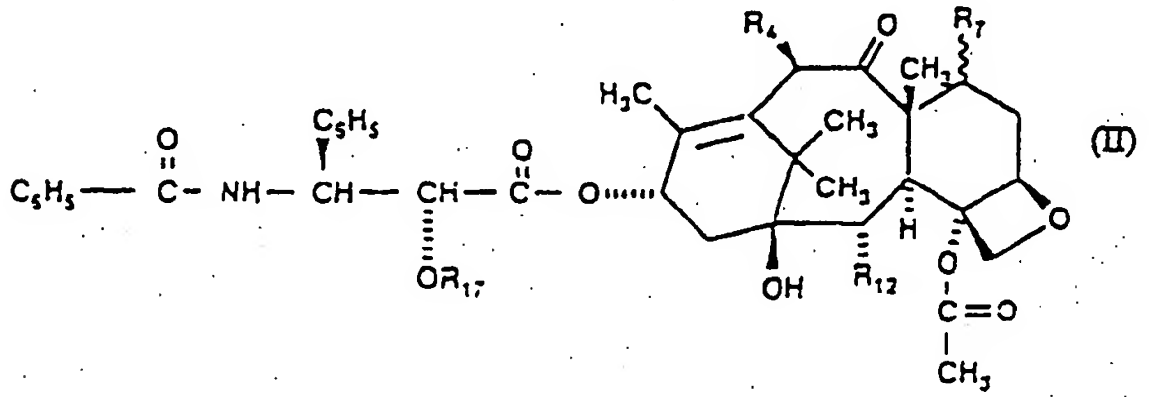
3. Méthode de la revendication 2, où ladite plante est sélectionnée parmi l'espèce *T. brevifolia, T. Baccata, T. x media, T. wallichiana, T. canadensis, T. cuspidata, T. floridiana, T. celebica* et *T. x hunnewelliana*.

4. Méthode selon l'une des revendications 1 à 3 où ledit au moins un taxane est taxol, 10-désacétylcéphalomannine, 7-épitaxol, 10-désacétyl-7-épitaxol, 7-épicéphalomannine, baccatine III, taxotère, 10-désacétylbaccatine III, céphalomannine, 10-désacétyltaxol, xylosyl taxol, xylosyl céphalomannine, 7-épibaccatine III, taxagifine, 8-benzoyloxy taxagifine, 9-acétyloxy taxusine, 9-hydroxy taxusine, taiwanxam, taxane Ia, taxane Ib, taxane Ic et/ou taxane Id.

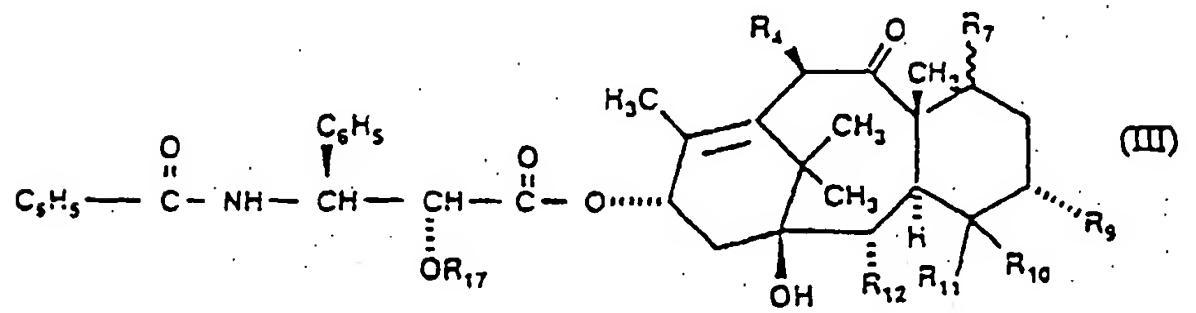
5. Méthode de la revendication 4, où ledit au moins un taxane est taxol, baccatine III, 10-désacétylbaccatine III. 10-désacéthyltaxol, xylosyl taxol, 7-épibaccatine III, 7-épitaxol et/ou 10-désacétyl-7-épitaxol.

6. Méthode de la revendication 5, où ledit taxane est taxol.

7. Méthode selon l'une des revendications 1 à 3, où ledit au moins un taxane est un taxane de la formule II et/ou III :



(II)



(III)

où

R_4	est céto (=O) ou acétyloxy ;
R_7	est hydrogène, α-hydroxy ou β-hydroxy ;
R_9	est acétyloxy, cinnamoyloxy ou hydroxyle ;
R_{10} et R_{11}	forment ensemble un groupe méthylène ou époxyde ;
R_{12}	est hydrogène, benzoyloxy ou acétyloxy ; et
R_{17}	est hydrogène ou acétyloxy.

8. Méthode selon l'une des revendications 1 à 7, où ledit tissu d'explant est supporté sur une masse flottante en membrane ou de l'éponge.

9. Méthode de la revendication 8, où ledit tissu d'explant est supporté sur une masse flottante en membrane.

10. Méthode de la revendication 9, où ladite masse flottante en membrane est du polypropylène microporeux ou de l'acétate de cellulose.

11. Méthode de la revendication 9 ou 10, où le niveau dudit milieu liquide est au-dessus du niveau de ladite masse flottante.

12. Méthode de la revendication 11, où des cellules dispersées de cal ou des amas de cellules dispersées sont formés et de plus où au moins une partie desdites cellules dispersées ou amas de cellules reste au-dessus du niveau de ladite masse flottante.

13. Méthode selon l'une des revendications 9 à 12, où ladite masse flottante est une structure poreuse où le diamètre moyen des pores est plus petit que le diamètre moyen des cellules dispersées individuelles.

14. Méthode selon l'une des revendications 1 à 13, où ledit milieu liquide est un milieu aqueux B5 de Gamborg, un milieu de Murashige et Skoog, un milieu de sels basiques de Rhododendron de Anderson ou un milieu de Whites.

15. Méthode de la revendication 14, où ledit milieu liquide est un milieu aqueux B5 de Gamborg.

16. Méthode selon l'une des revendications 1 à 15, où la partie dudit tissu d'explant qui est contact avec ledit milieu liquide est d'environ 10% à environ 25% du volume total dudit tissu.

17. Méthode pour la production d'au moins un taxane, comprenant les étapes de :

(A) induire des cellules de cal capables de produire au moins un taxane selon la méthode de l'une des revendications 1 à 16 ; et
(B) mettre lesdites cellules en culture dans un système liquide de culture de cellules en suspension pour produire lesdit(s) taxane(s).

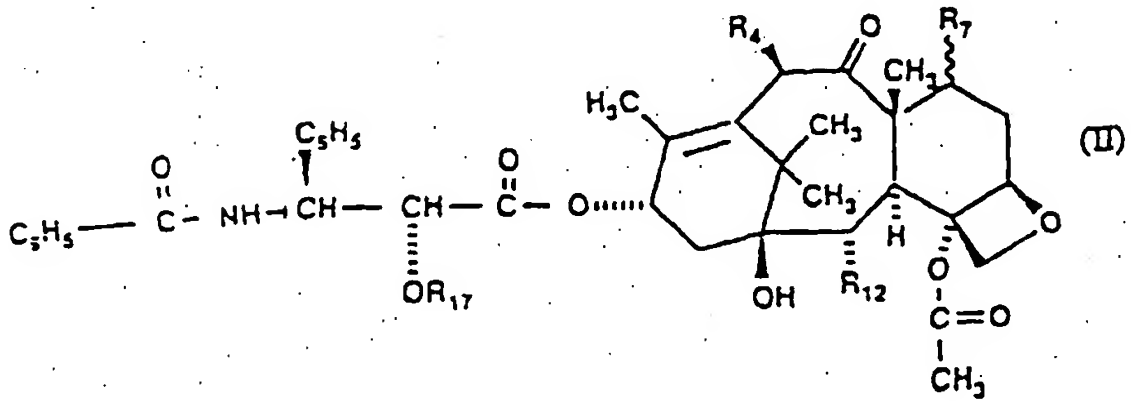
18. Méthode de la revendication 17, où aucune étape séparée de croissance ou de prolifération n'est employée subséquemment à l'étape (A) et avant l'étape (B).

19. Méthode de la revendication 17 ou 18, où ledit au moins un taxane est taxol, 10-désacétylcéphalomannine, 7-épitaxol, 10-désacétyl-7-épitaxol, 7-épicéphalomannine, baccatine III, taxotère, 10-désacétylbaccatine III, céphalomannine, 10-désacétyltaxol, xylosyl taxol, xylosyl céphalomannine, 7-épibaccatine III, taxagifine, 8-benzoyloxy taxagifine, 9-acétyloxy taxusine, 9-hydroxy taxusine, taiwanxam, taxane Ia, taxane Ib, taxane Ic et/ou taxane Id.

20. Méthode de la revendication 19, où on produit le taxol, la baccatine III, la 10-désacétylbaccatine III, le 10-désacétyltaxol, le xylosyl taxol, la 7-épibaccatine III, le 7-épitaxol, et/ou le 10-désacétyl-7-épitaxol.

21. Méthode de la revendication 20, où on produit du taxol.

22. Méthode de la revendication 17, où un taxane de la formule II et/ou III qui suit est produit :



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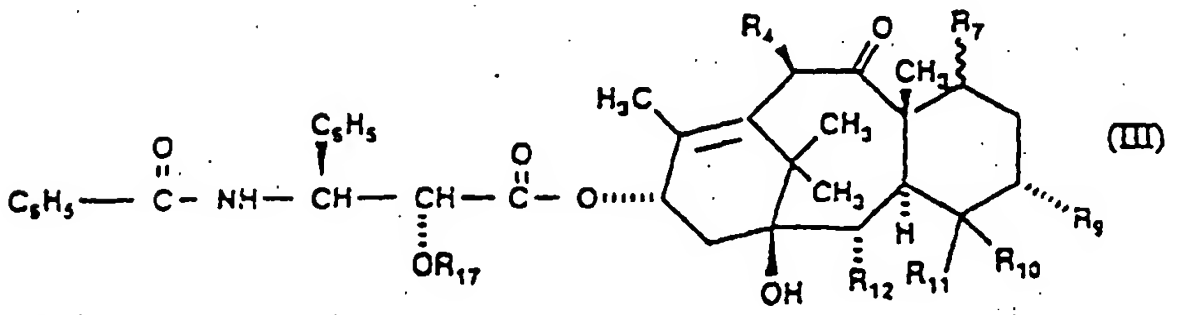

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R_{17}	est hydrogène ou acétyloxy.

23. Méthode selon l'une des revendications 1 à 16, où ledit tissu d'explant n'a pas encore été mis en contact avec un milieu artificiel liquide ou solide pour la formation des cellules de cal.

24. Méthode selon l'une des revendications 17 à 22, où ledit tissu d'explant n'a pas encore été mis en contact avec un milieu artificiel liquide ou solide pour la formation des cellules de cal.